

APPENDIX V

Determinants

Gallop apace bright Phoebus, through the sky—
—CHRISTOPHER MARLOW, *Edward II*

THE DETERMINANT THEORY was first enunciated by Teeple (1930, pp. 70–85). A determinant is a date which is believed to record the gain of the Maya year of 365 days over the solar year of approximately 365.2422 days in the interval between 13.0.0.0.0 4 Ahau 8 Cumku and the date in question. Teeple showed that the Maya calculated the accumulated error in one of two ways: they either noted the month position at 13.0.0.0.0 4 Ahau 8 Cumku which by their calculation then occupied the same position in the solar year as the given date did at the time then current; or they recorded the anniversary in the solar year then current of the position which, according to their calculations, the month position in question had occupied in the year 13.0.0.0.0 4 Ahau 8 Cumku.

These calculations frequently dealt with the month position on which the current katun fell. Thus, shortly before 9.17.0.0.0 13 Ahau 18 Cumku the Maya priest might have been interested in calculating how great an interval there was between the solar anniversary of the original 18 Cumku at 13.0.0.0.0 and the position occupied by 18 Cumku in the year then current. The interval between 13.0.0.0.0 and 9.17.0.0.0 is 1,418,400 days which reduces to 3883 solar years of 365.2422 plus about half a year. However, in the course of 3883 years 940 leap days have been inserted. The subtraction of 730 (2×365) from this total of leap days, gives 210 as the number of days the Maya calendar is ahead of the solar year. By subtracting 210 days from 18 Cumku the position 8 Mol is reached. That date then held the same position in the solar year at 13.0.0.0.0 4 Ahau 8 Cumku as 18 Cumku does at 9.17.0.0.0. The equation could be reversed, and the Maya priest could pose this problem: "The current katun ends on 18 Cumku, but what was the position in the solar year of 18 Cumku at 13.0.0.0.0?" To find its anniversary in the current year, add 210. Then, 18 Cumku + 210 = 3 Zac; accordingly, 3 Zac current time is the solar anniversary of 18 Cumku at 13.0.0.0.0. Perhaps this can be expressed better in terms of our own calendar. If 9.17.0.0.0 13 Ahau 18 Cumku falls on January 24, then according to the tropical year 8 Mol fell on January 24 at 13.0.0.0.0. Similarly, if 18 Cumku fell on August 22 at 13.0.0.0.0, that position in the solar year is at 9.17.0.0.0 occupied by 3 Zac.

At Copan the date 9.16.12.5.17 6 Caban 10 Mol is repeated on half a dozen monuments, and its katun and $1\frac{1}{2}$ katun anniversaries are also recorded; it is clearly the most important date at that city. Teeple identified it as a determinant of 9.17.0.0.0 13 Ahau 18 Cumku many years ago. As the date falls approximately eight years before 9.17.0.0.0, the correction should be two days less than for the latter date: 10 Mol + 208 = 18 Cumku. That is to say, 10 Mol occupied the same position in the solar year at 13.0.0.0.0 as 18 Cumku currently does (9.16.12.16.5 6 Chicchan 18 Cumku). It might be asked why the Maya chose 9.16.12.5.17 6 Caban 10 Mol rather than some other date, for instance 9.16.19.7.10 11 Oc 8 Mol, which has the advantage of being nearer the katun ending. I think that there were other factors which led to the election of 6 Caban 10 Mol, one of which is that Caban seems to have been a more popular day than Oc, but the choice may have been guided by a desire to establish a lunar relationship in harmony with that of the sun. The moon age of 9.16.12.5.17 is recorded on Temple 11 as 11 days. The Copanecs appear to have thought that 13.0.0.0.0 had a moon age of 22 days, and in that case the 10 Mol immediately following 4 Ahau 8 Cumku would also have had a moon age of 11 or 12 days. This may be coincidence, but I think there is enough evidence from other sources to suggest that the Maya sought to link the age of the moon with the solar relationships.

Copan, apparently, gave the reverse determinant of 9.17.0.0.0 on Altar Z, seeking the anniversary in current time of 18 Cumku at 13.0.0.0.0 4 Ahau 8 Cumku, as discussed above. The date is 9.16.18.9.19 12 Cauac 2 Zac which does not appear on the altar, but is implied by the following arrangement:

$$\begin{array}{r} (9.16.18.9.19 \quad 12 \text{ Cauac } 2 \text{ Zac}) \\ \quad \quad \quad 1.8.1 \\ \hline (9.17.0.0.0) \quad 13 \text{ Ahau } 18 \text{ Cumku} \end{array}$$

The correction should be 210 days; the equation is 18 Cumku + 209 = 2 Zac. It will be noted that 12 Cauac is the day before 13 Ahau. In this case there is no obvious lunar relationship.

At Piedras Negras 9.10.6.5.9 8 Muluc 2 Zip was carved on Stelae 33, 36, and 38, on L 2, and on MSS 1; its thir-

teenth tun and second katun anniversaries are declared respectively on Stelae 34 and 38. Of its importance, therefore, there can be no doubt. This date is the determinant of the current katun, 9.11.0.0.0 12 Ahau 8 Ceh, for it is the anniversary of 8 Ceh placed at 13.0.0.0.0 4 Ahau 8 Cumku. The interval is 3752 years requiring a correction of 179 days; the equation is 8 Ceh + 179 = 2 Zip. The moon age of 9.10.6.5.9 is recorded on Piedras Negras 36 as 4 days, and the moon age of 9.11.0.0.0 is given as four days by Pusilha K and as 5 days by Copan 13. The interval between the two dates (4931 days) is 167 moon less half a day. It therefore is probable that this date was chosen because it is linked to 8 Ceh both by solar and lunar calculations, although the lunar arrangement is different from that supposedly part of the 6 Caban 10 Mol equation.

On a jade in the Bishop collection occurs (9.10.10.16.14) 4 Ix 7 Zip. As this is followed by its katun anniversary, it is clearly a date of some importance. There is a possibility, however, that the date falls one CR later (Beyer, 1945). The interval of 3756 years requires a correction of 180 days. Here, the equation is the reverse of that just discussed. Instead of calculating the current anniversary of 8 Ceh placed at 13.0.0.0.0, the month position at 13.0.0.0.0 with the same solar position as 8 Ceh current time was sought: 7 Zip + 181 = 8 Ceh.

In the tun ending on 13.0.0.0.0 4 Ahau 8 Cumku 7 Zip should have had a moon age of 16 days, if 8 Cumku had a moon age of 22 days. The moon age of 9.10.10.16.14 4 Ix 7 Zip was 15 or 16 days. Here, again, there are both solar and lunar associations.

The recession of 8 Cumku in the solar year was also of interest to the Maya. Again, the solar position at 13.0.0.0.0 equivalent to 8 Cumku current time or the month position in the current year which held the same position as 4 Ahau 8 Cumku at 13.0.0.0.0 might be given.

Dates which recorded the solar equivalents at 13.0.0.0.0 of 8 Cumku current time are given in Table 21.

Date 1 has no obvious lunar associations, but note that it recovers 4 Ahau of 4 Ahau 8 Cumku.

Date 2 is given a moon age of 22 days, which, according to Teeple, was that of 13.0.0.0.0 4 Ahau 8 Cumku in the opinion of the Copanec priesthood of that time. This date falls 191 days before 9.12.8.13.0 4 Ahau 8 Cumku, which is distant 73 CR from 13.0.0.0.0 4 Ahau 8 Cumku. The appearance of this CR anniversary of the original 4 Ahau 8 Cumku undoubtedly inspired calculation of the associated determinant. As we shall see, the Maya made a special point of noting determinants or anniversaries of 8 Cumku in the vicinity of CR anniversaries of 4 Ahau 8 Cumku.

Date 3 has a moon age calculable from 9.12.6.5.8 as 10 days. The moon age of 12.19.19.8.9 8 Muluc 17 Mol would have been 10 days if Palenque reckoned the moon age of 4 Ahau 8 Cumku as 24 days. Date 3 is just one vague year before Date 2, and is also related to the current 4 Ahau 8 Cumku.

Date 4 has a moon age which can be calculated from the base of 9.12.6.5.8 as 6 days. The moon age of 14 Mol at 12.19.19.8.6 5 Cimi 14 Mol would have been 7 days if Teeple was correct in supposing that Palenque reckoned the moon age of 13.0.0.0.0 as 24 days. Of course, it follows that 8 Cumku at 13.0.0.0.0 had the same moon age as at 9.12.18.15.10 1 Oc 8 Cumku.

Date 5. The moon age of this date can be calculated as 21 days from 9.14.0.0.0 given on Piedras Negras 3 as 17 days. It is plausible that this was an attempt to reach the same moon age for Date 5 as was calculated for 13.0.0.0.0 4 Ahau 8 Cumku.

Date 6 has no apparent lunar link with 8 Cumku. This date is one year and 201 days before 9.15.1.8.0 4 Ahau 8 Cumku, which is distant 74 CR from 13.0.0.0.0 4 Ahau 8 Cumku. Presumably a date one year and 201 days before the CR anniversary was chosen because the Maya did not wish to give the date 201 days before 9.15.1.8.0 4 Ahau 8 Cumku because that would have been a date posterior to 9.15.0.0.0 4 Ahau 13 Yax, that of the erection of the monument. The Maya generally eschewed the practice of recording on a monument dates subsequent to that of dedication.

TABLE 21—DETERMINANTS OF 8 CUMKU

NO. OF INSCRIPTION	DATE	EQUATION	SOLAR
1. Copan 19.....	9.10.19.15. 0	4 Ahau 8 Ch'en	8 Ch'en + 180 = 8 Cumku 182
2. Copan H'.....	9.12. 8. 3. 9	8 Muluc 17 Mol	17 Mol + 191 = 8 Cumku 189
3. Palenque Cross.....	9.12. 7. 3. 4	7 Kan 17 Mol	17 Mol + 191 = 8 Cumku 189
4. Palenque Sun.....	9.12.18. 5.16	2 Cib 14 Mol	14 Mol + 194 = 8 Cumku 192
..... or.....	9.12.18. 5.17	3 Caban 15 Mol	15 Mol + 193 = 8 Cumku 192
5. Piedras Negras 8.....	9.14. 2.11. 9	6 Muluc 7 Mol	7 Mol + 201 = 8 Cumku 198
6. Calakmul 52.....	9.14.19.15.14	10 Ix 7 Mol	7 Mol + 201 = 8 Cumku 202
7. Yaxchilan L 14.....	9.15.10. 0. 1	4 Imix 4 Mol	4 Mol + 204 = 8 Cumku 204
8. Bonampak 2.....	9.17. 5. 8. 9	6 Muluc 17 Yaxkin	17 Yaxkin + 211 = 8 Cumku 213
9. Copan Q.....	9.17.19.11.17	5 Caban 15 Yaxkin	15 Yaxkin + 213 = 8 Cumku 215
10. Naranjo 8.....	9.18. 9.14. 3	11 Akbal 11 Yaxkin	11 Yaxkin + 217 = 8 Cumku 218

Date 7. There is again no obvious connection of a lunar character with 8 Cumku. The moon age of the current 8 Cumku for both Dates 6 and 7 is 7 days.

Date 8. 17 Yaxkin in the tun ending on 13.0.0.0.0 4 Ahau 8 Cumku (22 days) would have had a moon age of 17 days. The moon age of the current 7 Yaxkin can be calculated as 20 days.

Date 9 reveals no lunar associations.

Date 10 has no clear lunar basis, although the 11 Yaxkin after 4 Ahau 8 Cumku has a moon age of 22 days presumably the same as that calculated for 4 Ahau 8 Cumku.

Four of the ten determinants thus have both solar and lunar associations. In view of the various possibilities involved in each date these lunar associations may be merely fortuitous, although one imagines that the Maya would have been interested in thus hitting two birds with one stone.

Two interesting anniversaries of 13.0.0.0.0 4 Ahau 8 Cumku appear, respectively, on Quirigua G and Palenque Cross. The seventy-fifth CR anniversary of the original 4 Ahau 8 Cumku fell on 9.17.14.3.0 4 Ahau 8 Cumku. The correction at that date should have been 214 days, which, added to the anniversary of 4 Ahau 8 Cumku, reach 9.17.14.13.14 10 Ix 17 Yax; we find 9.17.14.13.12 8 Eb 15 Yax recorded on Quirigua G. On the Cross at Palenque the date 8.19.6.8.8 11 Lamat 6 Xul appears. This is one vague year and 123 days after 8.19.5.2.0, the sixty-eighth CR anniversary of 13.0.0.0.0 4 Ahau 8 Cumku. The interval is 3535 years, which calls for a correction of 2 years and 126 days. The Maya cal-

may have been regarded as unlucky, for 10 is the number of death, and Akbal and Xul have associations with the underworld.

Copan 16 carries the date 5 Ahau 8 Yaxkin. The glyphs are carved in an early style which indicates that the date has the LC position of either 9.4.9.17.0 or 9.7.2.12.0. If the earlier position is accepted, the date becomes a determinant of the seventieth CR anniversary of 4 Ahau 8 Cumku, which fell on 9.4.10.10.0, again one year removed:

9.4. 9.17. 0	5 Ahau 8 Yaxkin
7. 5 =	145 days subtract
9.4. 9. 9.15	3 Men 8 Cumku
1. 0. 5	365 days add
9.4.10.10. 0	4 Ahau 8 Cumku

The Maya equation is 8 Cumku + 145 = 8 Yaxkin; the true solar correction would be 8 Cumku + 151 = 14 Yaxkin. The accuracy is not remarkable, but the calculation was made at an early date. It was probably set one year earlier than the anniversary of 4 Ahau 8 Cumku so that the day Ahau might be recovered.

The manner in which determinants were calculated is not surely known, and it is obvious that more than one correction was used, for the Maya calculations may fall two or three days either side of the solar corrections. Teeple thought a solar-lunar equation was used; I am more inclined to think the correction was made in terms of the CR. Let us examine again those dates which are related to CR anniversaries of 4 Ahau 8 Cumku:

TABLE 22—DETERMINANTS OF 8 CUMKU NEAR CALENDAR ROUND ANNIVERSARIES

<i>Anniversary of 4 Ahau 8 Cumku</i>		<i>Determinant Date</i>	<i>Correction</i>	
<i>Date</i>	<i>No.</i>		<i>Maya</i>	<i>Solar</i>
A 8.19. 5. 2.0	68	8.19. 6. 8. 8 11 Lamat 6 Xul	+ 123 days	126 and 1 vague year
B 9. 4.10.10.0	70	9. 4. 9.17. 0 5 Ahau 8 Yaxkin	+ 145 days	151 less 1 vague year
C 9.12. 8.13.0	73	9.12. 8. 3. 9 8 Muluc 17 Mol	- 191 days	189
C' 9.12. 8.13.0	73	9.12. 7. 3. 4 7 Kan 17 Mol	- 191 days	189 and -1 vague year
C'' 9.12. 8.13.0	73	9.12. 8. 4. 5 11 Chicchan 13 Ch'en	+ 190 days	189 less 1 vague year
D 9.15. 1. 8.0	74	9.14. 19.15.14 10 Ix 7 Mol	- 201 days	201 and -1 vague year
E 9.17.14. 3.0	75	9.17.14.13.12 8 Eb 15 Yax	+ 212 days]	214

ulation is: 8 Cumku + 123 = 6 Xul. This is four days off, but may be a calculation made at an early date, before greater accuracy was attained. It is not clear why a date one year and 123 days after 8.19.6.8.8 4 Ahau 8 Cumku was chosen, although the earlier date, 10 Akbal 6 Xul,

Obviously different corrections are being applied, for no reasonably accurate system could lead to differences in corrections of 10 days in 52 vague years and 21 days in 104 vague years (differences between B and C, and B and D). Variations in the corrections at different times

and at different cities are to be expected. It will be noted that the poorest (B) is on the earliest monument, and the next poorest on the second earliest monument. Dates C and E fall two days short of the solar calculations; Date D is the same as would be reached by using a correct solar year.

Most of the CR anniversaries of 4 Ahau 8 Cumku during the period of the inscriptions appear in the list, but the important seventy-second anniversary at 9.9.16.0.0 is absent. It is possible that this was recorded on the hieroglyphic stairway at Naranjo. On Glyph Block 7 there is a distance number of 13.1, followed by 13 ? 18 Zip. Morley hesitatingly supports 13 Men 18 Zip; Spinden reads the date as 9.9.15.13.10 13 Oc 18 Zip; Joyce reads it as 12 Oc 18 Zip. Personally, I should be inclined to read the day sign as Akbal, since the lower part definitely resembles the glyph for that day. If, however, Spinden's reading is used, the following relationship develops:

$$\begin{array}{r}
 9.9.15. 3.10 \quad 13 \text{ Oc } 18 \text{ Zip} \\
 \underline{13. 1} \quad \text{Subtract} \\
 9.9.14. 8. 9 \quad 12 \text{ Muluc } 2 \text{ Ch'en}
 \end{array}$$

The second date is $2 \times 365 - 179$ days before 9.9.16.0.0. The solar correction at this date is 177 days; the Maya calculation would be 8 Cumku + 179 = 2 Ch'en.

If this reading is accepted, nearly all the CR anniversaries of 4 Ahau 8 Cumku during the period of the stela cult were accompanied by their determinants or solar anniversaries, calculated within a year or two of the dates in question. Those missing fell in early or late periods when very few calculations were being made. It is a fair conclusion, I think, that the Maya deliberately recorded the determinant or anniversary of 4 Ahau 8 Cumku as each CR anniversary of that date approached. If such dates are accepted as deliberate, it follows that the many other determinants are almost certainly the result of Maya calculations for the correction of their year, and are not coincidences.

The subject is vast and complex. I do not purpose to enter into further detail; enough has been written to outline the determinant theory, and for fuller information, the writer is referred to Teeple's discussion of the matter in *Maya Astronomy*.